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POWER SYSTEMS, INC.

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NEW 144-AUTO FERRIES PROJECT  
4420 14<sup>TH</sup> AVENUE NW - SEATTLE, WA 98107 Tel. 206-834-2329 Fax. 206-782-5455

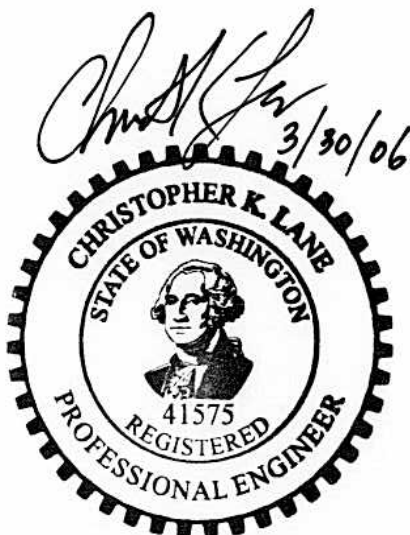
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Contract 00-6679

## ENGINEERING CALCULATION

# ENGINE COOLANT THERMAL EXPANSION

Calculation of allowable volume of Vessel Coolant System external to engine skid-mounted package inclusive of both Main Coolant and SCAC Coolant Systems that is accommodated by EMD Standard coolant expansion tank.



Performed by:

Date:

Chris K. Lane  
3/30/06

EXPIRES 9/30/07

## CALCULATION

**TITLE:** COOLANT EXPANSION – MAXIMUM “OFF-SKID” VESSEL COOLANT SYSTEM VOLUME ALLOWANCE

**PURPOSE:**

Determine the maximum allowable volume of coolant allowed to exist in vessel cooling system, that is coolant volume external to the PSI supplied engine package, that can be accommodated by the Coolant Expansion Tank without upset.

**SPECIFICATIONS AND ASSUMPTIONS:**

Specifications do not address specifics of expansion tank margins but engineering logic dictates that this expansion tank have sufficient capacity to support a full range of expected conditions with sufficient margin to prevent thermal expansion of coolant plus some allowance for normal fluid “losses” to be a burden on operators or in any way adversely impact Propulsion System reliability.

This calculation is somewhat unusual as it does not start with an understanding of the volume of the coolant systems because the Vessel portion of the systems, the Keel Cooler, SCAC Cooler, piping, etc. is “unknown”. Therefore this calculation estimates the MAXIMUM SYSTEM VOLUME ALLOWED FOR THE VESSEL SYSTEMS so that that result can be used as a constraint for Vessel design to follow. Hopefully, the Vessel system will have a much smaller total volume than the value that results from this calculation, with the difference representing the operating margin for errors in coolant fill inventory, fluid losses and other factors including inaccuracies in this calculation.

As such, the following assumptions thought to be consistent with project requirements have been used for this calculation:

- As the vessel is to be equipped with a Layover Heating System, the minimum coolant system temperature to be accommodated by the expansion tank that remains “in the normal operating range” above 80°F average temperature, but because the Vessel portion will not be maintained “hot” when in Layover, a calculation is provided a minimum of 40°F and is the limiting value recommended for use as the constraint for Vessel design purposes.
- The maximum coolant temperature to be accommodated by the expansion tank shall be 215°F, to accommodate maximum possible over-temperature conditions before control shutdown. This is based on a limiting assumption where raw water cooling from the vessel cooling system is lost and the engine overheats to the maximum shutdown set point. This is a very conservative assumption as it would not logically ever occur to both the main and SCAC systems simultaneously and in actuality only the hot leg of the loops could ever reach this limit, the cold leg would be cooler even with a loss of vessel cooling.

- The “normal” operating range for the 85 gallon (nom.) capacity expansion tank is from 50% to 85%, volume leaving 35% or about 30 gallons for expansion.
- Coolant is 100% water, no glycol or other additive that would significantly influence the volumetric expansion coefficient.<sup>1</sup>
- Volume of coolant added by SCAC on-skid piping is based on conservative estimate of 30 Ft. total length of 4-inch Sch. 40 pipe for supply & return and 20 Ft. or 3-inch sch. 40 branch pipe to/from individual after coolers. The exact layout of these pipes was not yet available when this calculation was completed.

#### REFERENCES:

1. Detroit Diesel Engine Division Percent Increase in Volume for Water and Anti-Freeze Solution (undated) (Attachment 1).
2. EMD 710 Data Book (2003) Page B-3 for tank capacity of 85 gallons.
3. Email from EMD indicating Main and SCAC combined coolant volumes. (Attachment 2).
4. Valley Coolant Schematic Drawing 1-77270-033
5. Crane “Flow of Fluids” B-16 & B-17 Pipe Data for pipe transverse areas (Att. 3).

#### CALCULATION:

##### Maximum Total Volume in Combined Engine and Vessel Coolant System:

Percent Volume Change (see Attachment 1):

- Volume change 80°F (Pt. 1) to 215°F (Pt 2) = 4.5% - 0.35% = 4.15%
- Volume change 40°F (Pt. 1) to 215°F (Pt 2) = 4.5% - 0% = 4.5%

Maximum Total Coolant System Volumes for 40% Tank Surge:

$$\begin{aligned} V_{\max} (80 \text{ to } 215) &= V_{\text{surge}}/4.15\% = 30 \text{ gal}/4.15\% \\ &= 30/0.0415 = \underline{723 \text{ gallons}} \end{aligned}$$

$$\begin{aligned} V_{\max} (40 \text{ to } 215) &= V_{\text{surge}}/4.5\% = 30 \text{ gal.}/4.5\% \\ &= 30/0.045 = \underline{667 \text{ gallons}} \end{aligned}$$

##### Volume of SCAC “On-Skid” Piping (pipe area from Att. 3):

Volume of 30 Ft of 4-inch Sch. 40 Pipe	= 30 ft. x 0.0884 ft <sup>2</sup>
	= 2.65 ft <sup>3</sup>
Converted to gallons	= 2.65 ft <sup>3</sup> x 7.48 = 19.8 Gal.

Volume of 20 Ft of 3-inch Sch. 40 Pipe	= 20 ft. x 0.0513 ft <sup>2</sup>
	= 1.03 ft <sup>3</sup>
Converted to gallons	= 1.03 ft <sup>3</sup> x 7.48 = 7.7 Gal.

<sup>1</sup> No glycol confirmed with G. Duncan 8/23/05.

$$\text{Volume of SCAC "On-Skid" Piping} = 19.8 + 7.7 = 27.5 \text{ Gal.}$$

Total Volume of Engine Main and SCAC "On-Skid" Systems:

Coolant in Engine (Main & SCAC)	= 95 Gallons (Att. 2)
Coolant in Assy Rack before Mods	= 91 Gallons (Att. 2)
Coolant in added Main Coolant Piping	= 0 Gallons
Coolant in added SCAC Piping 4"	= 27.5 Gallons
Coolant in Expansion Tank Cold (40%)	= 30.8 Gallons (40% of 77 Gal)
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Total On-Skid Coolant Volume	= 244.3 Gallons

Maximum Coolant in "Off-Skid" Vessel Coolant Systems – Main and SCAC combined:

$$\text{Off-Skid } V_{\max} (80 \text{ to } 215) = \underline{723 \text{ gal.} - 244 \text{ gal.} = 479 \text{ Gallons (Nom. 480 Gal.)}}$$

$$\text{Off-Skid } V_{\max} (40 \text{ to } 215) = \underline{667 \text{ gal.} - 244 \text{ gal.} = 423 \text{ Gallons (Nom. 425 Gal.)}}$$

CONCLUSION – Vessel cooling system total volume for combined Main Coolant and SCAC systems for all "Off-Skid" piping, heat exchangers, etc. should be limited to 425 Gallons and would better be limited to about 300 Gallons.